Road safety prediction on the basis of ethically sound physiological measurements - IVORY

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HEARTMETRICS EXPERTS

Artificial Intelligence for Road Safety and Mobility Workshop

8th UN Global Road Safety Week

Athens, 15 May 2025

ROAD SAFETY

Streets for Life
#MakeCyclingSafe

The IVORY project

IVORY

- IVORY:

  "AI for Vision Zero in Road Safety"
  ivory-network.eu

- Partners:

  4 Universities
  8 Non-academic partners
  13 Associated Partners
  10 Countries

- Duration of the project:

  48 months (November 2023 – October 2027)

- Framework Program:

  This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No 101119590

Co-funded by the European Union

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PhD Goals

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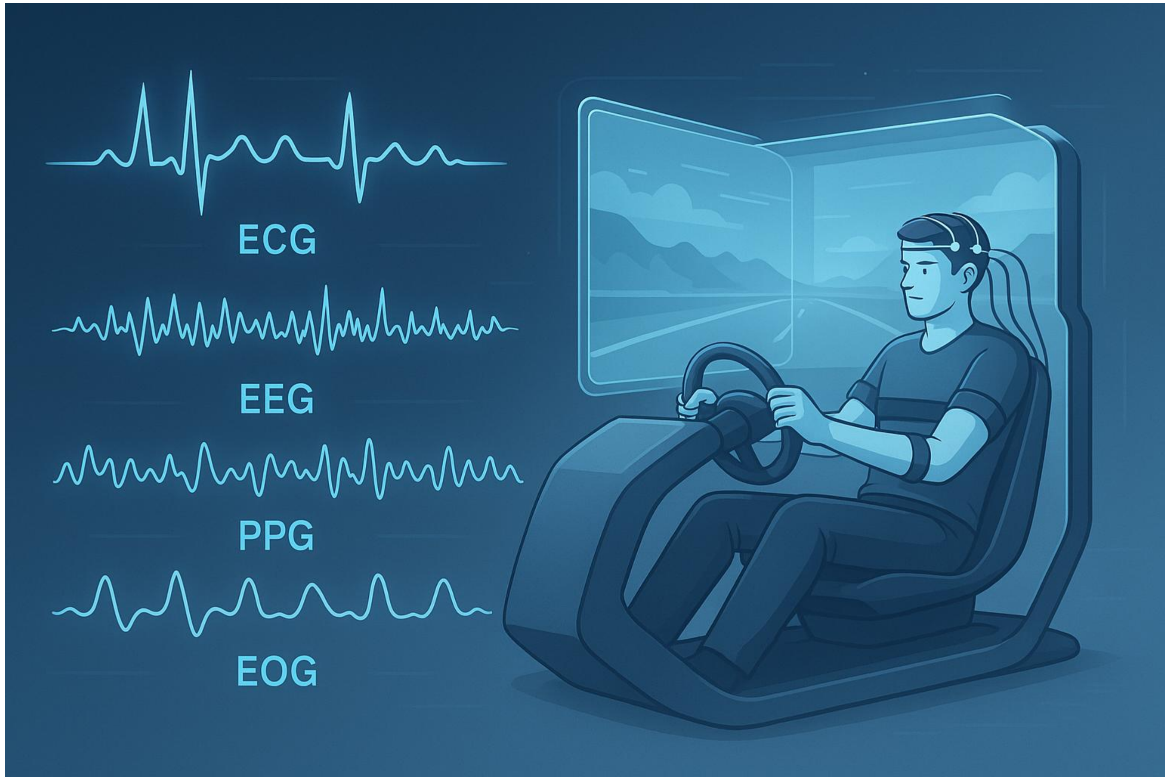
- To exploit physiological measures obtained from naturalistic driving to create accurate and reliable real-time road safety models.

- To investigate scenarios, involving (i) individual driving scenarios and (ii) driver interaction scenarios.

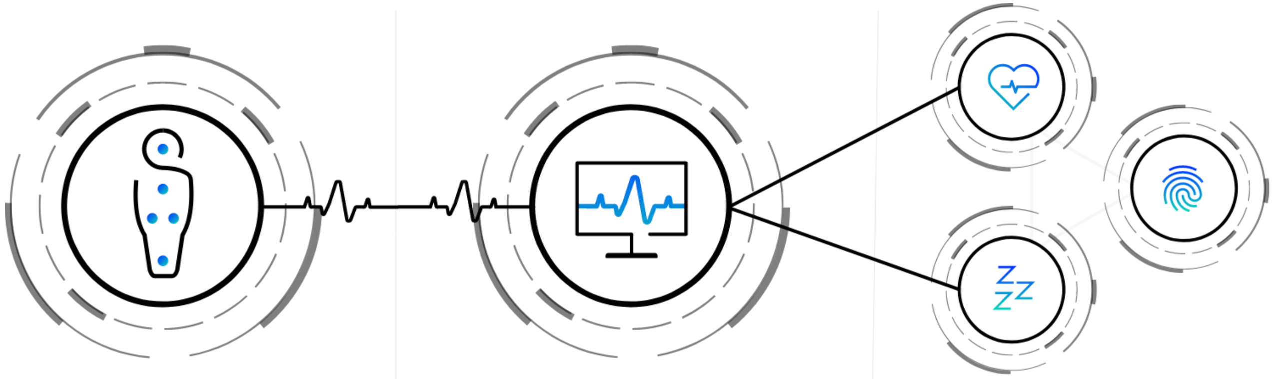
- To explore the ethical dimensions of driver physiological measurements in road safety assessments, the type of biases that may arise, and how these can be eliminating for more objective and fair traffic safety assessments.

Dataset

- Valu3s dataset (VTI)
  - Physiological data
    - CardioWheel
    - Chest Strap
  - Psychomotor Vigilance Task (PVT) reaction times
  - Simulation data
    - Steering wheel angle (SWA)
    - Karolinska Sleepiness Scale (KSS)
    - Distances ahead and behind
    - Line crossing
    - etc.



Acquisition – Processing - Prediction



Signal Acquisition through non-intrusive sensing technology

Processing and multivariate analysis of Cardiac signals combined with context information

Driver's Health State and Well-being

Driver Biometric Identification

Drowsiness and Fatigue

Continuous Monitoring

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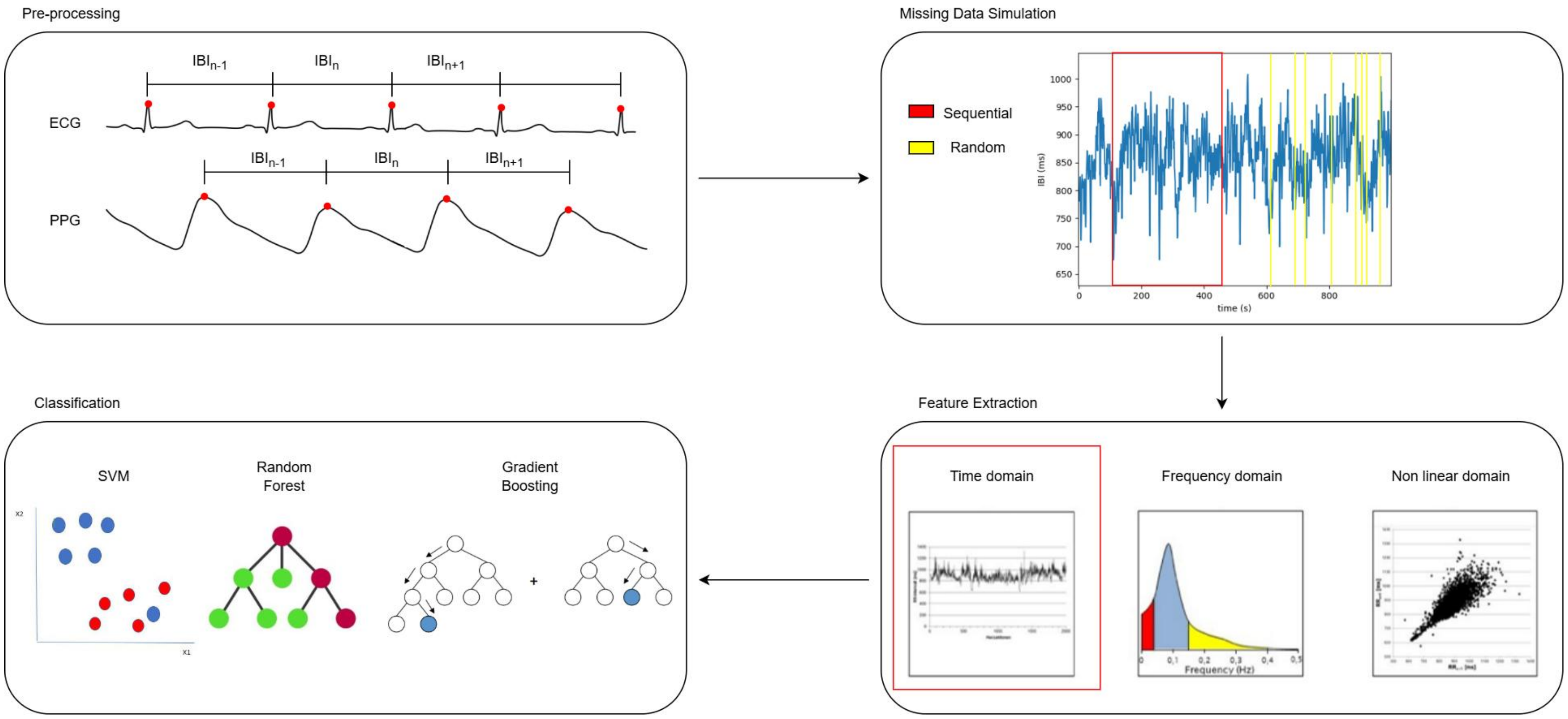
Methodology



Results So Far

- Developed a baseline machine learning pipeline that utilizes Heart Rate Variability (HRV) features extracted from cardiac signals to detect driver drowsiness.

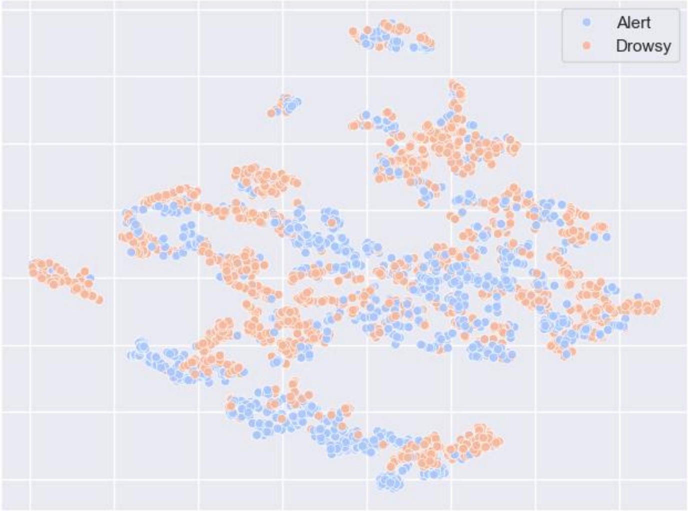
- Impact of missing inter-beat intervals (IBIs) on HRV features and driver drowsiness detection (submitted @ IEEE ITSC 2025)

- Built a deep learning pipeline leveraging Long Short-Term Memory (LSTM) networks to model temporal patterns in HRV data for detecting driver drowsiness.

Model	Metric	Baseline	Random Missing Data		Sequential Missing Data	
			15%	30%	15%	30%
SVM	Accuracy	71.20 ± 3.0	70.10 ± 2.8	69.55 ± 2.4	70.13 ± 2.5	70.71 ± 2.3
	Precision	71.41 ± 3.1	70.39 ± 2.9	69.90 ± 2.4	70.32 ± 2.6	70.95 ± 2.4
	Recall	71.20 ± 3.0	70.10 ± 2.8	69.56 ± 2.4	70.13 ± 2.5	70.71 ± 2.3
	F1-score	71.13 ± 3.0	69.98 ± 2.8	69.40 ± 2.4	70.05 ± 2.5	70.62 ± 2.3
	MCC	42.60 ± 6.2	40.48 ± 5.8	39.44 ± 4.9	40.44 ± 5.1	41.65 ± 4.7
RF	Accuracy	78.77 ± 2.6	77.38 ± 2.3	74.26 ± 1.6	77.38 ± 1.6	75.90 ± 2.0
	Precision	78.80 ± 2.5	77.47 ± 2.2	74.38 ± 1.4	77.44 ± 1.6	75.97 ± 2.0
	Recall	78.77 ± 2.6	77.38 ± 2.3	74.26 ± 1.6	77.38 ± 1.6	75.90 ± 2.0
	F1-score	78.76 ± 2.6	77.35 ± 2.3	74.22 ± 1.7	77.37 ± 1.6	75.89 ± 2.0
	MCC	57.57 ± 5.2	54.85 ± 4.5	48.64 ± 3.1	54.82 ± 3.2	51.88 ± 4.1
GB	Accuracy	75.82 ± 1.9	74.66 ± 2.5	72.76 ± 2.0	74.40 ± 2.5	72.76 ± 2.0
	Precision	75.93 ± 2.0	74.77 ± 2.4	72.86 ± 2.0	74.49 ± 2.5	72.86 ± 2.0
	Recall	75.82 ± 1.9	74.66 ± 2.5	72.76 ± 2.0	74.40 ± 2.5	72.76 ± 2.0
	F1-score	75.79 ± 1.9	74.63 ± 2.5	72.72 ± 2.0	74.37 ± 2.5	72.72 ± 2.0
	MCC	51.75 ± 3.9	49.44 ± 4.9	45.62 ± 4.0	48.89 ± 5.1	47.46 ± 4.1

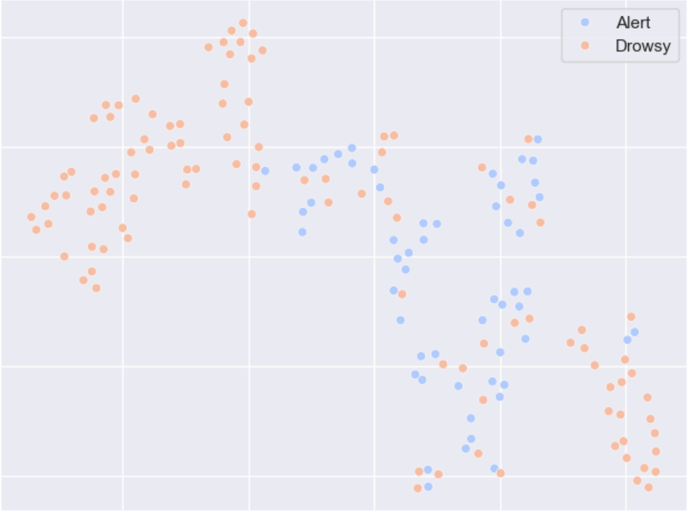
Results So Far

tSNE plot across all Participants



tSNE plot for Participant 1

tSNE plot for Participant 5



Streets for Life

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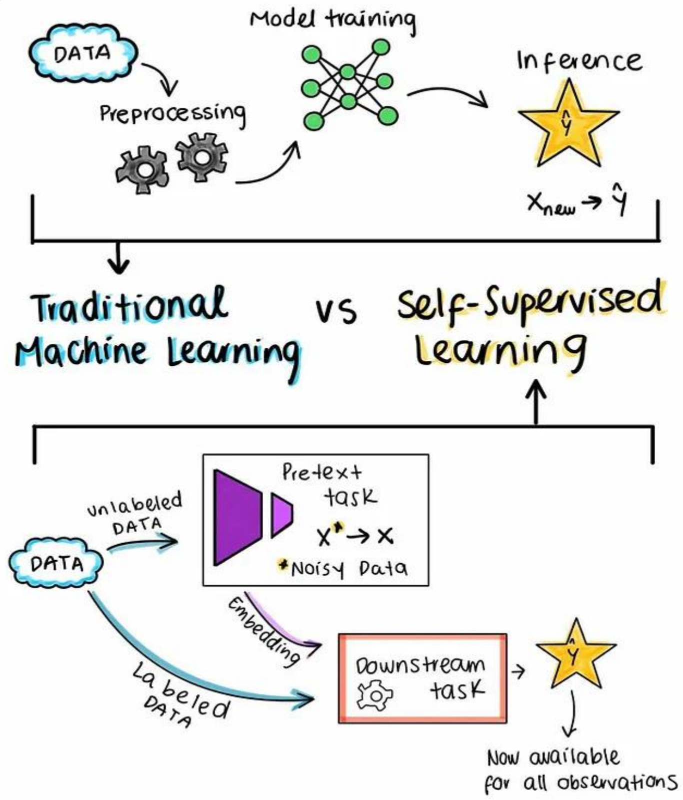
- Professional drivers, who often endure long hours behind the wheel, will benefit from continuous physiological monitoring during extended trips.

- Detect early warning signs of health events, such as cardiac arrest, especially in young or vulnerable drivers.

- Monitor driver's physiological state and issue alerts when rest is necessary, thereby preventing crashes before they occur.

Scientific and Social Impact

- Integrate ECG with additional modalities for a more comprehensive understanding of the driver's state.
- Design personalized models tailored to individual physiology and behavior.
- Enable real-time, on-device AI to ensure privacy and ethical compliance.



Future Challenges

- Ensuring ethical use of biometric data in AI systems, with a focus on consent, transparency, and the prevention of misuse or surveillance-based discrimination.

- Balancing personalization with privacy in physiological monitoring, as models become more adaptive and reliant on sensitive biometric signals like ECG.

- Building trustworthy and explainable AI for safety-critical applications, where predictions directly impact human lives and must be interpretable by both engineers and end users.

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